[0085] Next, in step 1514, the performance of inductor 500 is simulated through the use of three dimensional electromagnetic modeling software. Suitable modeling software products include IE3D by Zeland Software, Inc. of Fremont, CA, and Microwave Office by Applied Wave Research Inc. of El Segundo, CA. In step 1516, it is determined whether the simulated performance is acceptable. If so, then the procedure continues to step 1518. Otherwise, the procedure returns to step 1502, where Equation (1) should be used as a guide in this iterative process to indicate how the inductor dimensions and number of turns should be modified to obtain the desired inductance.

[0086] In step 1518, a circuit application for the inductor implementation may be simulated to determine whether the circuit exhibits desired performance characteristics. As an example, this step may comprise simulating a diplexer circuit (described below with reference to FIGs. 16 and 17) using a radio frequency (RF) circuit simulator. Examples of RF circuit simulators include MMICAD by Optotek Ltd. of Kanata, Ontario Canada, Microwave Office by Applied Wave Research Inc. of El Segundo, California, and Touchstone and ADS/MDS by Agilent Technologies, Inc. of Palo Alto, California.

[0087] The inductors may be modeled in this step as S-parameter tables, or equivalent circuits, derived from the software used in step 1516. An exemplary performance characteristic that may be analyzed in this step is the diplexer frequency response. In step 1520, it is determined whether the performance characteristics are acceptable. If so, then the procedure is complete. Otherwise, the procedure returns to step 1502.

## IV. Exemplary Application Environment

[0088] The description now turns to an example environment in which the invention may be implemented. The present invention is particularly useful in communications nodes. FIG. 16 illustrates an exemplary communications node 1600 (also referred to herein as communications device 1600). Communications

node 1600 may be a cable modem diplexer, or other devices, as would be apparent to persons skilled in the relevant art(s). Communications node 1600 includes a diplexer 1612, a receiving amplifier 1614, a transmitting amplifier 1616, a receiver 1618, and a transmitter 1620. Receiver 1618 may include a television tuner.

**[0089]** Communications node 1600 exchanges signals with a shared medium 1602. Shared medium 1602 provides node 1600 with a communications bandwidth (e.g., a portion of the electromagnetic spectrum) for the exchange of signals. As shown in FIG. 16, a coaxial cable is an exemplary implementation of shared medium 1602. However, shared medium 1602 may include other implementations, such as a wireless radio frequency (RF) spectrum. In this wireless RF implementation, communications node 100 includes an antenna (not shown) coupled to diplexer 1612 that exchanges RF signals with RF spectrum 1602.

**[0090]** This exchange of signals is performed according to a full-duplex approach, where communications node 1600 transmits signals over a first portion of the communications bandwidth and a receives signals over a second portion of the communications bandwidth. These first and second portions of the bandwidth are referred to herein as an upstream portion and a downstream portion, respectively.

**[0091]** Diplexer 1612 enables this full-duplex functionality. Namely, diplexer 1612 isolates receiver 1618 from receiving signals originated by transmitter 1620. Furthermore, diplexer 1612 protects sensitive circuitry within receiver 1618 from powerful signals that are originated by transmitter 1620 and amplified by transmitting amplifier 1616.

**[0092]** Diplexer 1612 includes a downstream filter 1622 and an upstream filter 1624. As illustrated in FIG. 16, both downstream filter 1622 and upstream filter 1624 pass signals having frequencies within bandwidths 1626 and 1628, respectively. Bandwidth 1626 is within the downstream portion of the shared

medium 1602 spectrum, while bandwidth 1628 is within the upstream portion of the shared medium 1602 spectrum.

[0093] Diplexer 1612 may be implemented on a printed circuit board (PCB) that includes various elements. Examples of these elements include integrated circuit(s), RF and low-frequency connectors, and discrete electronic components. These elements may be surrounded by a housing made of a conductive material, such as sheet metal. For such PCB implementations, filters 1622 and 1624 include inductors and capacitors that are assembled upon the PCB.

[0094] FIG. 17 is a circuit schematic illustrating implementations of filters 1622 and 1624. As shown in FIG. 17, both downstream filter 1622 and upstream filter 1624 include a plurality of capacitors and inductors. Downstream filter 1622 filters signals received at a node 1720 and outputs these filtered signals at an output node 1722. In contrast, upstream filter 1624 filters signals received at an input node 1730 and outputs these filtered signals at an output node 1732.

[0095] Downstream filter 1622 includes a network of capacitors 1702a-e and 1706a-d, and inductors 1704a-d. This network provides a pass band from 54 to 860 MHz or higher. Upstream filter 1624 includes a network of capacitors (1712a-c, 1714a-c, and 1714a-d) and inductors (1708a-c and 1710). This network provides a pass band from 0 to 42 MHz.

[0096] The inductors in the circuit of FIG. 17 may be implemented using implementations of multiple layer inductor 500. As such, FIGs. 18A and 18B are views of diplexer 1612 implemented on a PCB 1802 that include a plurality of multiple layer inductors 500. These diplexers do not include an attached metallic housing.

[0097] As described above, these inductor implementations advantageously provide smaller footprints than single layer printed inductors. Furthermore, such multiple layer inductors are less costly than discrete inductors. In addition, the aforementioned shielding features of these multiple layer inductors allows minimal spacing between components without electromagnetic interference and without the attachment of a bulky metallic housing. Therefore, the present